Echocardiography as a Means to Evaluate Potential Performance in Horses

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The Horse as a Premier Mammalian Athlete?

- Maximal oxygen uptake relative to body mass of elite racehorses ~200 ml kg\(^{-1}\) min\(^{-1}\)
- The fastest recorded Quarter horse 55 mph

![Etruscan shrew](image1)

*Etruscan shrew*

300 ml kg\(^{-1}\) min\(^{-1}\)

![Cheetah](image2)

*Cheetah 70 mph*

400 ml kg\(^{-1}\) min\(^{-1}\)

![Pronghorn antelope](image3)

*Pronghorn antelope*

300 ml kg\(^{-1}\) min\(^{-1}\)
Special Adaptations of the Thoroughbred Cardiovascular System

- Proportionally larger heart per unit body mass
- Heart rate range from 20 to 240 beats min$^{-1}$
- Proportionally larger spleen per unit body mass
- Splenic red cell reserve able to double packed cell volume and oxygen delivery during maximal exercise

↑ Cardiac output and arterial oxygen content
Do Horses With Big Hearts Run Faster?

**Pharlap**, winner of 57 races
6 kg – 20% larger than an average racehorse

**Secretariat**, record breaking American racehorse - Over 10 kg???
Maximal CO$>500$ l min$^{-1}$
$VO_2$max 240 ml kg$^{-1}$ min$^{-1}$!!!
• Significant linear relationship between British Horseracing Board official rating and heart size measured by echocardiography in 200 horses engaged in National Hunt racing (Young & wood 2001).

• No such relationship have so far reliably been found when horses employed in flat racing were examined. VO$_2$max and heart size are more important predictors of performance for equine athletes running longer distances (Young et al. 2003).
• Significant strong relationship between left ventricular mass and other measurements of cardiac size and $\text{VO}_2\text{max}$ in 18 Thoroughbred racehorses exercising on a high speed treadmill (Young et al. 2002).
The “Heart Score” Concept (Steel et al. 1963)

- A relationship between mean value of QRS interval, measured in msec using the standard three bipolar leads recording, and heart weight in horses.
- Statistically significant correlation between the same electrocardiographic values and the total amount of prizes won in races.
- The HS as a valuable indicator of potential performance.
The “Heart Score” concept (steel et al. 1963)

- The QRS interval (intraventricular conduction time) represents the time required for the electric wave to spread and depolarize the ventricular mass. Hence, as the ventricular muscular mass increases, a longer time will be necessary for the ventricular depolarization to take place.

But…
• HS shows a relationship neither with the body weight nor with ventricular muscular mass, as determined by echocardiography. It does not correlate with the heart size and cannot be regarded as an index for predicting potential performance (Lightowler et al. 2004)
• Sample size n=34
• Sex, race, body weight and other important factors not taken into account
• Effects of training on the heart were not considered
• Influence on heart weight and ecg of potential specific pathologies effecting the chosen sample, was not adequately investigated
• Intrinsic error in carrying out the measurements
• The concept of “Wave front” ventricular depolarization does not apply to hoofed species.

Lightowler et al. 2004
Ventricular Depolarization in the Horse

• The beginning and the end of the QRS interval does not necessarily correspond to the beginning and the end of the ventricular depolarization.

• In the horse the depolarization process differs from that of small animals because of the very wide spread distribution of the purkinje network. The fibers extend throughout the myocardium and ventricular depolarization takes place from multiple sites. The electromotive forces therefore tend to cancel each other out, consequently no wavefronts are formed. The overall effect of the ventricular depolarization on the ECG is minimal.

Cardiology of The Horse, Marr Celia, 1999.
Ventricular Depolarization in the Horse

• The overall effect of the ventricular depolarization on the ECG is minimal, therefore the duration of the QRS complex in horse does not depend on the spread of the wavefront across the ventricles.

• Physiological myocardial hypertrophy cannot prolong the equine QRS duration as it does in predators.

• Equine ECGs provide little or no information about the relative or absolute sizes of the ventricles.

Cardiology of The Horse, Marr Celia, 1999.
Earlier studies emphasized a tight correlation between body weight (BW), body surface area (BSA) and left ventricular myocardial mass (LVMM) measured by means of a guided M-Mode echocardiography (Lightowler et al. 2000)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Small ponies 125–306 kg</th>
<th>Large ponies 274–469 kg</th>
<th>Horses 540–620 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interventricular septal thickness in diastole (cm)</td>
<td>1.7 ± 0.3</td>
<td>2.4 ± 0.2</td>
<td>2.8 ± 0.2</td>
</tr>
<tr>
<td>Interventricular septal thickness in systole (cm)</td>
<td>2.3 ± 0.4</td>
<td>3.8 ± 0.5</td>
<td>4.6 ± 0.5</td>
</tr>
<tr>
<td>Left ventricular interventricular diameter in diastole (cm)</td>
<td>6.1 ± 1.0</td>
<td>8.9 ± 1.4</td>
<td>11.2 ± 0.8</td>
</tr>
<tr>
<td>Left ventricular interventricular diameter in systole (cm)</td>
<td>3.8 ± 0.4</td>
<td>5.9 ± 0.9</td>
<td>7.3 ± 0.8</td>
</tr>
<tr>
<td>Left ventricular free-wall thickness in diastole (cm)</td>
<td>1.6 ± 0.4</td>
<td>2.2 ± 0.5</td>
<td>2.5 ± 0.3</td>
</tr>
<tr>
<td>Left ventricular free-wall thickness in systole (cm)</td>
<td>2.2 ± 0.4</td>
<td>2.7 ± 0.8</td>
<td>3.8 ± 0.3</td>
</tr>
<tr>
<td>Aortic diameter in diastole (cm)</td>
<td>3.9 ± 0.5</td>
<td>5.9 ± 1.0</td>
<td>7.8 ± 0.6</td>
</tr>
<tr>
<td>Variable</td>
<td>Image plane</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
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<tr>
<td><strong>M-mode echocardiography</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left ventricular diameter in diastole (cm)</td>
<td>RSXC</td>
<td>11.92</td>
<td>0.76</td>
</tr>
<tr>
<td>Left ventricular diameter in systole (cm)</td>
<td>RSXC</td>
<td>7.45</td>
<td>0.615</td>
</tr>
<tr>
<td>Fractional shortening (%)</td>
<td>RSXC</td>
<td>37.42</td>
<td>3.86</td>
</tr>
<tr>
<td>Interventricular septal thickness in diastole (cm)</td>
<td>RSXC</td>
<td>2.85</td>
<td>0.278</td>
</tr>
<tr>
<td>Interventricular septal thickness in systole (cm)</td>
<td>RSXC</td>
<td>4.21</td>
<td>0.463</td>
</tr>
<tr>
<td>Interventricular septal thickness fraction (%)</td>
<td>RSXC</td>
<td>48.27</td>
<td>15.4</td>
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<tr>
<td>Left ventricular free-wall thickness in diastole (cm)</td>
<td>RSXC</td>
<td>2.32</td>
<td>0.382</td>
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<tr>
<td>Left ventricular free-wall thickness in systole (cm)</td>
<td>RSXC</td>
<td>3.85</td>
<td>0.414</td>
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<tr>
<td>Left ventricular free-wall thickening fraction (%)</td>
<td>RSXC</td>
<td>69.01</td>
<td>22.9</td>
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<tr>
<td>Left atrial appendage diameter (cm)</td>
<td>RSX</td>
<td>6.2</td>
<td>0.737</td>
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<tr>
<td>Aortic diameter in diastole (cm)</td>
<td>RSX</td>
<td>7.95</td>
<td>0.534</td>
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<tr>
<td>Aortic diameter in systole (cm)</td>
<td>RSX</td>
<td>8.13</td>
<td>0.579</td>
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<tr>
<td><strong>Two-dimensional echocardiography</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left atrial diameter in diastole (cm)</td>
<td>LLX</td>
<td>12.82</td>
<td>0.782</td>
</tr>
<tr>
<td>Left atrial diameter in systole (cm)</td>
<td>LLX</td>
<td>12.87</td>
<td>0.782</td>
</tr>
<tr>
<td>Aortic diameter at valve in diastole (cm)</td>
<td>RLX</td>
<td>7.20</td>
<td>0.344</td>
</tr>
<tr>
<td>Aortic diameter at valve in systole (cm)</td>
<td>RLX</td>
<td>7.58</td>
<td>0.378</td>
</tr>
<tr>
<td>Aortic sinus diameter in diastole (cm)</td>
<td>RLX</td>
<td>8.72</td>
<td>0.504</td>
</tr>
<tr>
<td>Aortic sinus diameter in systole (cm)</td>
<td>RLX</td>
<td>9.02</td>
<td>0.495</td>
</tr>
<tr>
<td>Aortic sinotubular junction in diastole (cm)</td>
<td>RLX</td>
<td>7.45</td>
<td>0.388</td>
</tr>
<tr>
<td>Aortic sinotubular junction in systole (cm)</td>
<td>RLX</td>
<td>7.70</td>
<td>0.407</td>
</tr>
<tr>
<td>Pulmonary artery diameter (cm)</td>
<td>RIO</td>
<td>6.11</td>
<td>0.491</td>
</tr>
<tr>
<td>Left ventricular area in diastole (cm²)</td>
<td>RSXC</td>
<td>100.9</td>
<td>10.64</td>
</tr>
<tr>
<td>Left ventricular area in systole (cm²)</td>
<td>RSXC</td>
<td>40.84</td>
<td>6.90</td>
</tr>
<tr>
<td>Myocardial area in diastole (cm²)</td>
<td>RSXC</td>
<td>223.0</td>
<td>15.21</td>
</tr>
<tr>
<td>Myocardial area in systole (cm²)</td>
<td>RSXC</td>
<td>191.1</td>
<td>16.82</td>
</tr>
<tr>
<td>Fractional area change (%)</td>
<td>RSXC</td>
<td>59.53</td>
<td>4.98</td>
</tr>
</tbody>
</table>

RSXC, right parasternal short-axis image at the chordal level; RSX, right parasternal short-axis image; LLX, left parasternal long-axis image; RLX, right parasternal long-axis image; RIO, right ventricular inflow-outflow image.
Echocardiography and electrocardiography as means to evaluate potential performance in horses.

Lightowler C, Piccione G, Giudice E, del Olmo GR, Cattaneo ML.

Departamento de Medicina, Faculty of Veterinary Sciences, University of Buenos Aires, 1427-Buenos Aires, Argentina.
Objective: test the use of echocardiography for accurate measurement in order to calculate Left Ventricular Myocardial Mass (LVMM) and to predict performance.
• 48 Thoroughbreds and half-bred TB race horses aged between 17 and 25 months, males and females.
• Cardiologically healthy (clinical evaluation, routine echocardiography, ECG).
• 3.5 MHz dual mechanical sector transducer.
• Calculation of Left Ventricular Myocardial Mass: M-Mode guided images captured from the right parasternal window, in short axis, at the chordae tendinae level.

Lightowler et al. 2004
M-Mode guided images captured from the right parasternal window, in short axis, at the chordae tendinae level:
Measurements Taken:

- Left Ventricular Diastolic Diameter (LVDD)
- Diastolic Thickness of the Interventricular Septum (DTIS)
- Diastolic Thickness of the Left Ventricular Wall (DTLVW)

**Formula used to determine LVMM:**

\[ 1.5(DTIS + DTLVW + LVDD)^3 - (LVDD)^3 \]

- For all measurements obtained values correspond to 6 recordings made by different Echotomograms.

Lightowler *et al.* 2004
Results

- Echocardiography is a valuable instrument for the assessment of potential performance.
- Echocardiography allows performing of a clear anatomical evaluation and accurate measurements in order to assess LVMM.
- LVMM may be a valid tool for predicting potential performance, this index should only be evaluated in fully grown and untrained horses.
- On this basis, the obtained value may correspond to the genetically determined heart size that is the only value suitable for selecting horses for future performance.

Lightowler et al. 2004
Stress Echocardiography and its Role in Performance Assessment

Virginia B. Reef, 2001

Section of Sports Medicine and Imaging
Department of Clinical Studies
University of Pennsylvania
• The diagnostic technique of choice for evaluating the horse with suspected subclinical myocardial disease.

\[ FS\% = \frac{\text{LVIDd} - \text{LVIDs}}{\text{LVIDd}} \times 100 \]

Reef 2001
Is There An Upside To Selective Breeding For Performance?

- In contrast to other companion animals species, selecting horses for performance has left the species almost entirely free of the inherited and acquired cardiac diseases.
- Breeding the horse for speed has, for the most part, been good for his heart.
- If only development of the equine lung had kept up with that of the heart and skeletal muscle, then the horse might truly have become invincible.....

Young 2003
…”we owe this species an apology for causing it to endure our lack of understanding for thousands of years. Equus has been my teacher, my friend, and my provider”.

(Monty Roberts)